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Socio-Economic Sustainability of Biofuel Production in Sub-Saharan Africa:

Evidence from a Jatropha Outgrower Model in Rural Tanzania

By Elisa Portale

HARVARD Kennedy School
Belfer Center for Science and International Affairs

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Belfer Center for Science and International Affairs
Harvard Kennedy School
79 JFK Street
Cambridge, MA 02138
Fax: (617) 495-8963
Email: belfer_center@harvard.edu
Website: http://belfercenter.org

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Socio-Economic Sustainability of Biofuel Production in Sub-Saharan Africa: Evidence from a Jatropha Outgrower Model in Rural Tanzania

By Elisa Portale*

Environment and Natural Resources Program
Belfer Center for Science and International Affairs

Sustainability Science Program
Center for International Development

Harvard Kennedy School, Harvard University
79 John F. Kennedy Street
Cambridge, MA 02138
USA

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*Giorgio Ruffolo Doctoral Fellow in Sustainability Science in the Sustainability Science Program at Harvard's Center for International Development 2008-2009.

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Comments are welcome and may be directed to Elisa Portale at elisa.portale@gmail.com. This paper is available at www.belfercenter.org/enrp.

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1. Introduction

1.1. Background

Adequate and affordable energy supply is considered the key to economic development, wealth generation, and the transition from subsistence agricultural economies to modern industrial and service-oriented societies. Energy is related to the social, economic and environmental dimensions of sustainable development (Munasinghe, 2002). Energy services improve social and economic wellbeing and access to energy is a crucial component to relieving poverty, improving human welfare, and raising living standards (UNDESA, 2005). Recent hikes in oil prices, energy security and climate change concerns drive the growing demand for biofuels. In Africa, there is a growing interest for biofuel projects by foreign private investors, as well as increasing support from bilateral and multilateral donors towards incorporating biofuels into Governments' development plans and energy policies.[1] For non-oil producing African countries, biofuel production has the potential to partially displace costly oil imports. Biofuels also have the potential to provide a new market, income opportunities, and economic growth in rural areas and their production may stimulate improvements in local infrastructure and eventually broaden development.[2] A number of African governments have responded to this demand by establishing task forces to assess their countries' potential to competitively produce biofuels, interact with foreign investors, and help draft biofuels policies. Optimism over biofuels is matched by skepticism. Many biofuel investments involve large plantations schemes and put pressure on vulnerable ecosystems.[3] Skeptics also view biofuels as a "land grabbing" opportunity for foreign speculators. The most problematic view is that biofuels are a potential threat to food security. Given limited land resources and low farm productivity in developing countries,

[1]Bioenergy actors have focused on biofuel as a way to extend available energy in the context of increasing demand for transportation fuel or as a substitute for more carbon intensive energy. Others see biofuel as an economic opportunity in term of potential market in which to invest (Lee et al., 2008). The use and development of alternative sources of energy is increasingly encouraged in Western countries, with private and public financial support.
[2] Opportunities for rural development should be the key priority for the biofuel sector in developing countries (Hazzel and Pachauri, 2006). Biofuel feedstock production development may promote collection and conversion facilities located in rural areas and the construction and operation of those facilities will generate additional economic activity in rural areas, emphasizing the close link between the biofuels sector and rural development.
[3] In particular, Giampietro et al. (2005) emphasizes the enormous environmental costs that would accompany a large-scale expansion in biofuels production, and a potentially large loss in food production capacity. If correct, large-scale use of bioenergy would not be a realistic option for addressing global climate change and oil dependence because biofuels increase demand for land, water, and labor – though the focus was shifted to the desirability and sustainability of such an energy transition. Farmers direct benefits are linked to the production scheme.

biofuels could displace food crop production and reduce already inadequate food supplies. Investment in biofuel production has the potential to transform the economy, landscape, and standard of living. Hence, to maximize benefits, the promotion of biofuels needs to be carefully planned and sustainably implemented. Sub-Saharan Africa in particular has seen a rising tension between governments' desire to promote investments in biofuels to supply local or international markets and their desire that this new business benefit local farmers and villages and increases economic growth in rural areas.

This paper broadens the measurement of sustainable development by reconsidering the socio-economic approach at a different level of analysis, making use of a case study. Typically, socio-economic implications are measured in terms of material gains and economic indices, such as employment and income. This paper enlarges this approach and the analysis also includes non-material goods such as relationship, wellbeing, and perceptions. This addition is based on literature that supports the view that any measure of sustainable development could not lack the wellbeing and social capital of relationships measurements (Parris and Kates, 2003). The link between wellbeing and sustainable development corresponds to the sense that a higher level of sustainable development means a higher level of wellbeing, and thus a higher of quality of life (Dasgupta, 2001). Subjective wellbeing may be difficult to translate into measurable indicators, but starting from the existing literature, this research presents a theoretical framework for the integration of the social and economic connections in an outgrower scheme for biofuel feedstock production. The outgrower scheme is implemented by the Dutch Company, Diligent Ldt., which contracts local farmers to produce Jatropha feedstock and offers a guaranteed minimum price for purchase, a long-term contract and free inputs (seeds and training). Diligent was chosen as a case study because it proposes a potentially good practice model.[4] The Diligent strategy aims to ensure food security and land tenure of small farmers. This paper investigates whether an outgrower scheme for a Jatropha production project in Tanzania is capable of developing "socio-economic sustainable outcomes for farmers." Furthermore, the answer relies on the inclusion of

[4] Diligent started to invest in Jatropha feedstock in Tanzania in 2006, implementing an outgrower scheme. Diligent's approach seems to be in line with the indications of Tanzanian government that in its "Guidelines for liquid biofuels sustainable production" (Ministry of Energy and Minerals, March 2009 Draft) clearly encourages investments in non-food crops and specifically in models that avoid farmers' displacement from their settlements. See section 2.2. for the Diligent case study description.

an analysis of the farmers' material benefits and subjective perceptions about the overall welfare contribution of the outgrower scheme. This research is the first to propose a practical way to operationalize such an analysis and to apply it to a concrete investment project. The key questions posed in this paper are:

1) **Is it profitable for farmers and companies to produce Jatropha straight vegetable oil (SVO) by implementing an outgrower scheme in Tanzania?**
   - Is it possible to maximize the direct material benefits for farmers?
   - Is the Jatropha SVO business sustainable in the long run?
   - Is Jatropha SVO price-competitive with diesel?
2) **How can Jatropha SVO production be considered socio-economically sustainable for farmers?**
   - Can Jatropha SVO maximize the social benefits for farmers at the local level in terms of perceived access to services?
   - Can Jatropha SVO enhance farmers' subjective wellbeing, social capital, gender equality, food security, and environmental consciousness?
3) **Are there good practices and structures that can be implemented by biofuel investors in order to ensure that rural farmers benefit from the project?**

1.2. Methodological framework

The socio-economic sustainability of an investment project such as the one initiated by Diligent relies on two aspects: i) the economic feasibility of the specific project in the long run; and ii) the impact of the private sector activity in bioenergy production on the farmers' income, their perceptions (subjective wellbeing, environment preservation, access to services, food security, and social capital), and business capabilities (access to resources, entrepreneurship skills, agricultural investment, and provision of a reliable market). In particular, the socio-economic drivers of sustainability are interpreted in three dimensions: performance, perception, and the peculiarities of the structure and characteristics of the outgrower scheme. The resulting sustainability matrix (Figure 1) is a valuable tool for assessing the socioeconomic status and potential of rural areas in developing countries. It is applied to an outgrower scheme for Jatropha production in rural areas of Tanzania.

Figure 1: Socio-economic drivers of sustainability

Drivers	Description
Integrated performance (business viability)	Long term market; Income generation; Poverty alleviation
Farmers' perception	Economic access to services; Subjective wellbeing; Food security; Gender equality; Environmental preservation; Social capital generation
Structural outcome or characteristics	Provision of inputs (seeds); Skill transfer and technology; Guaranteed price and access to reliable markets; Access to credit and subsidized land preparation

To answer the first research question, an economic performance analysis was carried out. The economic feasibility evaluation of the project in the long run is necessary in order to protect farmers who have invested in Jatropha production as outgrower. The performance analysis covers:

- Estimation of Jatropha seeds production cost and opportunity-cost for farmers
- Potential income creation for farmers and direct monetary benefits
- Straight vegetable oil (SVO) and byproduct business analysis and potential market creation
- SVO and oil price competitiveness.

The second research question is answered by presenting a socio-economic assessment framework that includes farmers' individual perceptions, self-assessment, and evaluation of their quality of life. The hypothesis is that the introduction of Jatropha cultivation in the village induces significant changes in farmers' perceptions related to several areas of socio-economic sustainability. The structural outcome will help to answer the third question through the qualitative description of the outgrower model and considerations on good practices and policies. The structural outcome or characteristics of the outgrower model comprises a set of good practices induced by the scheme that could ensure sustainability and provide an answer to the government's desire to create a local market for biofuels at a competitive price and ensure tangible benefits for local villages. The research is based on economics of Jatropha data[5] and original farmers' data collection to describe the potential opportunities for rural smallholders. The farmers' socio-economic investigation was conducted through the use of a "household

[5] Data used in analyzing the economics of Jatropha and for the general assessment of the potential of producing Jatropha biofuels were mainly obtained through review of documentary materials and numerous interviews with Diligent general management, Diligent field officers, and relevant stakeholders.

survey questionnaire."[6] The analysis combines both quantitative and qualitative tools. This study's findings can be considered a stepping-stone to more in-depth research because of the early stage of the project's implementation to date and the small sample surveyed. Further empirical monitoring and evaluation of Jatropha projects is required to provide relevant information for governments and investors. Section 2 provides an overview of Jatropha activities in Tanzania, presents the Diligent case study focusing on the outgrower scheme business model, and briefly presents the study area. The economic viability of Jatropha production – for both the company and farmers – is explored in Section 3 and different possible scenarios and sensitivity analysis are presented. Section 4 analyzes qualitative and quantitative data to describe farmers involved in Jatropha production and discuss the potential social implications of the scheme. Section 5 presents concluding remarks and makes policy recommendations.

2. Jatropha activities in Tanzania

2.1. National policy and Jatropha investments in Tanzania

Biofuels have been identified as a possible solution to diversify the portfolio of renewable energy options in Tanzania[7] and the government recognizes the need for alternative and strategic fuel development to reduce oil imports. Although the government has not yet established a separate policy regime to regulate biofuel production, a National Biofuel Task Force[8] was founded in 2006 to establish guidelines that recognize the risks of the displacement of people due to investment in large-scale plantations.[9] Guidelines are presented to address the sustainability of bioenergy production and in particular refer to the need to control land use to prevent food

[6] The survey was conducted in January 2009 in Kiswahili, a local language, with the assistance of three research assistants. Further information and data were gathered through extensive participant observation, informal conversation, walking in farms and fields, and attending conferences and workshops. All interviews were conducted personally, using an interpreter. Minor translation problems or misunderstandings may have occurred. Interview questions were prepared ahead of time and were further refined during the first days of fieldwork. Careful explanation about the independence and purpose of the study was given during the interviews. All data was entered by one person. Errors in the basis for data analysis should be negligible.

[7] The National Energy Policy of 2003 boosts investment in renewable energy, appropriate and efficient technologies, and the need to implement indigenous sources of energy. In 2005, the Rural Energy Act established the Rural Energy Board, Fund and Agency and they are responsible for energy access in rural areas and development of modern energy services. They offer grants and subsidies to promote rural energy projects, but only in the Petroleum Act in 2008 has biofuel been officially included as a possible alternative to petroleum.

[8] The National Biofuel Task Force is guided by the Ministry of Planning, Economy and Empowerment.

[9] In this regard, it affirms, "no forced displacement of people should be allowed for biofuels development. Resettlement is a sensitive issue that shall be handled with care. It is therefore encouraged to use out-growers model or hybrid model i.e. plantation and out-growers schemes" (Ministry of Energy and Minerals of Tanzania, 2009, p. 21).

production substitution, avoid deforestation or biodiversity reduction due to biofuel plantations, and ensure control of water sources. Investors are encouraged to specify the role of outgrowers in the production chain and the benefit they will gain from the project and outgrowers are invited to form associations/cooperatives to become involved in the value-adding activities. Further indications are provided regarding the positive socio-economic impact that biofuel investments may have.[10] There are 35 national and international companies and NGOs currently active in the Tanzania biofuel industry and most are in Jatropha biodiesel production. The main reasons why Jatropha has been highly promoted by the Tanzanian government to attract investors are that Jatropha adapts to semi-arid lands (46% of Tanzania) and it is a non-food crop. Farmers are familiar with Jatropha since the plant is already present in some regions of the country and has been used locally for traditional medicine. Jatropha is drought resistant and can be planted in arid and semi-arid soil, can grow rain-fed, and limits soil erosion. Lastly, Jatropha is a perennial tree and is easy to grow and maintain.[11] A widespread adoption of Jatropha could potentially benefit the rural population through employment and income for small-holders. In particular, the dry season does not overlap with the main crop harvesting season so harvesting Jatropha can provide extra income in rural areas without interfering with other major farm activities. In addition to transportation use,[12] Jatropha SVO can substitute traditional biomass use in poor households, reducing indoor air pollution (Sagar et al., 2007) and it can be use for lighting (using oil lamps),[13] cooking (substituting charcoal and as stove briquettes for cooking purpose with seed

[10] The benefits should accrue to the local community in terms of employment and investment return. The task force invites investors to develop appropriate infrastructure and to engage communities in the projects. The investors should involve local stakeholders as local authorities as well as involve people in the project design and implementation. In addition the project should contribute at least 2% of revenues in improving social, economic, and environmental services at the project area. Investors should ensure that up to 5% of land acquired for biofuels production will be used to grow relevant food crops and they are obliged to assist in providing extension services for food as well as biofuels. Intercropping food crops and biofuels should be given due consideration.

[11] Maintenance costs for land preparation and seedlings occur in the first year; pruning and chemicals are required in the first three years. Harvesting is by hand and very labor intensive and in large-scale, the labor cost is expected to make up between 35- 50% of the total cost of oil (Kempf, 2007).

[12] At the stage of production, a commercial market for Jatropha oil and its by-products does not yet exist (Caniëls and Romijn, 2009). Diligent sells Jatropha SVO to Safari companies in Arusha as sustainable fuel in modified car engines. The University of Technology in Eindhoven (TUE), Netherlands, supports Diligent experiments on the use of Jatropha oil in diesel engines (Rabé, 2004).

[13] Kerosene lamps are widely used in the villages, but using Jatropha oil is expensive because a separate lamp with a thicker wick than usual is required. It is a very interesting market to explore and is connected more to rural development and socio-economic sustainability.

cakes), and electrification[14] (multifunctional platform and generators). Regardless of scale, development of a Jatropha-based biofuel sector in Tanzania is in the very early stages, and its future is still unclear. Jatropha has considerable potential for combining energy supply and development and promises to be economically viable for investors, but prominent barriers within Tanzania's existing energy and agricultural regime remain. Barriers include infrastructural and logistical problems; technical skill and knowledge gaps; a limited local research infrastructure; cultural barriers associated with traditional uses of Jatropha; psychological obstacles from known poisonous qualities of the crop; and a considerable price disadvantage for Jatropha oil vis-à-vis traditional fuel, except in remote locations. Nonetheless, straight vegetable oil (SVO) is nationally promoted as a "sustainable niche market product" (Van Eijck et al., 2008), but there is a potential for the expansion of the SVO local market due to potentially significant increases in oil prices in the international market.

2.2. Case Study: Diligent and outgrower scheme business model

Diligent Tanzania, Ltd. was established in 2004 as a joint venture between the Dutch Diligent Energy Systems and Tanzanian Multiflower. Diligent Energy Systems is a company focusing on production of environmentally and socially sustainable biofuel and it is attracted to the Tanzanian market by the potential of Jatropha as a source of SVO first and biodiesel second. Diligent Tanzania (referred to from now on as Diligent) decided to invest in an outgrower scheme to avoid social tensions related to land ownership and labor conditions.[15] The overriding factor behind the choice of the outgrower scheme is linked to a specific corporate social responsibility orientation.[16] Diligent has a network of 3,000 outgrowers in five different regions

[14] Projects on rural electrification by using a multifunctional platform for electricity generation are already in place in Mali, India, and Tanzania. (Brew-Hammond et al., 2004)

[15] Diligent implemented an outgrower scheme to reflect its social responsibility mission: "Diligent wants to contribute both to reduction of global warming, and to creation of employment in developing countries. The overall objective is triple profit: profit for society, for the environment, and an adequate profit for itself." (Diligent website).

[16] Biofuel investments can be organized as a large scale plantation or a small scale contracting model (outgrower). These different systems have negative and positive impacts on several variables such as scale economies, rural population development, and environment (Woods et al., 2007, Milder et al., 2008) and require appropriate policy implementation to assure positive outcomes (Bekunda et al., 2009). FAO (2009) has shown how small-scale bioenergy initiatives can offer new choices in rural communities to establish development strategy and livelihood improvement by creating direct farmer participation. The outgrower scheme is able to stabilize income and strategize agricultural development (Sriboonchitta et al., 2008). In the long run, small farmers are able to accumulate production and management skills, thus improving their bargaining power. Contract farming provide growers with an assured market, stable income, access to firm's services, ease of credit, and technical knowledge and it provides the firm with an assured supply of material less fixed investment, and low maintenance costs. Considerable evidence

for a total area of 3,500 hectares (2008) and it scaled up production to 10,000 hectares (2009). Diligent encourages farmers to plant Jatropha trees as hedges[17] around their field to protect the food crop from animals and mark boundaries so that outgrowers can manage their own land and make it more productive rather than being displaced from it. Jatropha is grown on existing or unused farmland with limited inputs. There is no need to clear any land from the forest to plant Jatropha, giving it a substantial environmental advantage over large-scale plantations. Diligent's approach is based on prompting producers to become risk-takers and induce them to be open to technology transfers.[18] Diligent asks rural farmers to sign a ten-year contract, according to which the farmers became outgrowers and receive free inputs (seeds) and training from Diligent and Diligent guarantees purchases for ten years. A minimum purchase price insures farmers against potential fluctuations in the oil or Jatropha international markets. Monitoring is continuous and farmers are visited often to maintain their commitment. For these purposes, Diligent has trained several field officers who must build trust with outgrowers and provide advice and technical support. Diligent establishes several collection centers in the production areas to store Jatropha bags to be collected by Diligent. Furthermore, Diligent is pursuing added value creation by transforming the byproduct of the pressed Jatropha seeds into "cakes" that can be used as fertilizer[19] or a local fuel source. According to Diligent, Jatropha production is most feasible in the small scale system. Diligent leans towards outgrower scheme for several reasons in particular:[20]

a) Jatropha production is very labor intensive[21] and mechanization is unavailable.
b) Growing Jatropha in large plantations can generate land competition problems.[22]

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suggests the existence of technology spillovers when farmers associated with outgrower schemes adopt improved technologies for other crops (Strasberg, 1997; Benfica, 2006; Uaiene, 2008).

[17] Alternatively farmers are advised to intercrop Jatropha with a staple crop in order to limit soil erosion. Hence, this minimizes land use competition, giving rural farmers the chance to increase land value and obtain extra income.

[18] From this perspective, behavioral changes are not observable yet, but it is an important issue for further research.

[19] The seedcake contains nitrogen and can be used as fertilizer even after it has been used in biogas production, as it will still contain nutrient and minerals. Using the seedcake as fertilizer is one of the major benefits in Jatropha production – both for the soil and the energy balance – as indirect energy saving while avoiding expensive commercial fertilizer (FACT, 2006).

[20] Based on several interviews with Ms. Janske van Eijck, General Manager, Diligent, in Tanzania in January 2009.

[21] Jatropha requires almost 50 workers for every 100 hectares planted, (sugarcane requires only 34 workers per 100 hectares), but Jatropha is three times less capital intensive than sugarcane (Arndt et al., 2008).

[22] Large plantation investments require the acquisition of large amounts of land. Smallholders who are being displaced from their land cannot effectively negotiate terms. Unequal power relations in the land acquisition deals can put the livelihoods of the poor at risk, in particular when there is not a formal title to the land, but it is used

c) Growers' diversification protects investors from risks from loss and damages.

d) Jatropha investment can spread out benefits in different communities (i.e. supplying energy) as well as promote small public investment in infrastructure in different villages simultaneously.

e) Jatropha oil is generally processed and marketed locally and may provide cheaper fuel than imported and transported diesel fuel for many regions.

f) Outgrower schemes promote farmer participation and entrepreneurship, foster technology transfers, and increase land value for small farmers.

g) Jatropha in particular can create a cash crop market in areas where no other business is possible, creating a win-win situation for investors and farmers.

On the other hand, the outgrower model is not without risks for Diligent, such as feedstock supply guarantees and high expenses for training programs. Outgrowers potentially receive shares of revenue from this system and benefits are related to improvement of agricultural techniques, knowledge creation, market development for the new crop, additional income provision, and improved access to services. On top of this, there are direct improvements in agricultural productivity thanks to enhanced crop diversity, restoration of unproductive lands, and enhanced soil fertility. In the long run, the outgrower system could be more socially sustainable than the large-scale model (in terms of integrating economic profit with the preservation of the environment and the promotion of social development) as long as outgrowers are able to cooperate with the community and participate in the investments decisions.[23] In support of this view, economies of scale are less applicable to large-scale Jatropha plantations due the limited potential of mechanization, especially when compared with the economies of scale achievable when growing sugarcane. In general, the pro-poor implications connected to the production scheme have been investigated in several studies (FAO, 2009; Arndt et al., 2008; and Dubois, 2008). Arndt et al. (2008) indicate how the outgrower approach to biofuel production with Jatropha is more pro-poor than sugarcane capital-intensive plantation industries due to the greater use of unskilled labor and accrual of land rents to smallholders in this system. Moreover, the expected benefits of outgrower schemes will be further enhanced if they result in technology

under customary tenure arrangements. Von Braun et al. (2009) emphasize how the bargaining power in negotiating land-lease agreements in rural areas is sometimes totally on the side of the foreign firm.

[23] Some authors suggest that the best solution, for sugar cane production in particular, is a hybrid model that integrates outgrower and large scale models, following sustainability criteria and participation process (Bekunda et al., 2009). An example of hybrid initiative is the case of Tanzania Kilombero Sugar Company, which integrates outgrower with large scale model. The case shows that the higher the production in the large scale estate, the greater the value gained by the local communities through the out-grower scheme because a share of the profits is retained locally and the local communities have benefited (Bekunda et al., 2009).

spillover to other crops. However, Hausmann (2007) argues that plantation schemes tend to be more labor-intensive and hence more pro-poor. In addition, large scale biofuel production requires general investment in roads and port infrastructure and it can "crowd in" other investments due to transport infrastructure improvements providing inter-industry spillovers (Hausmann and Wagner, 2009). Other possible positive spillovers include resources for new agricultural technologies and practices as well as future global price stability and increased production. This argument is convincing for areas that succeed in attracting substantial initial private investment. On the other hand, many areas are so remote (especially in Sub-Saharan Africa) and the required investment in public infrastructure so large that only a small fraction of potential large scale production sites is eventually successful. The advantage of the outgrower scheme is that it promotes small yet widespread potential development and agricultural upgrading on top of providing biofuel to areas that would not qualify for large-scale investment, but may still profit from cheaper, locally-produced biofuel that could displace imported and/or more polluting sources of energy. Furthermore, outgrower schemes can promote rural development and attract new investments. A brief overview of the geographic area and the sample is presented in the next section.

2.2.1. Sample characteristics

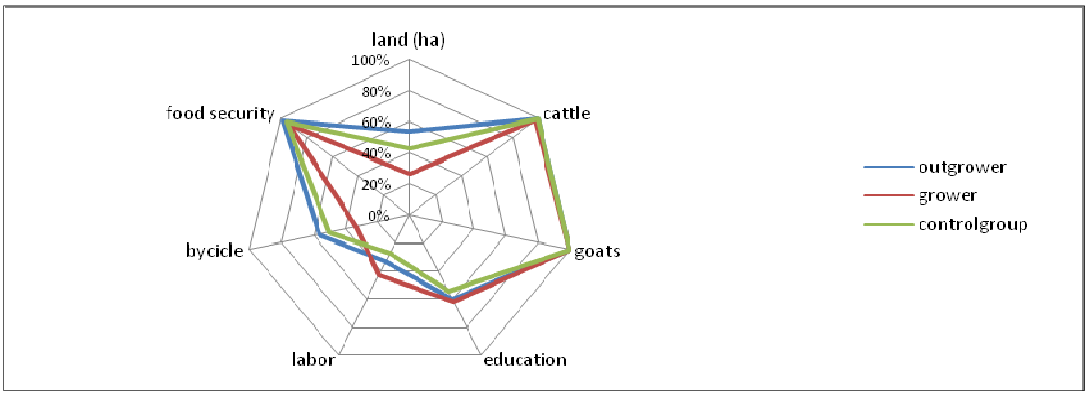
Two out of the five regions where Diligent operates were chosen in developing the sample design. Any farmer interested in cultivating Jatropha may join meetings and sign a contract with Diligent. Therefore, data were collected (see footnote 6) for different household categories of small holder farmers randomly assigned as: a) Jatropha farmers contracted by Diligent (outgrowers); b) Jatropha farmers not contracted, but selling Jatropha to Diligent (growers);[24]and c) non Jatropha farmers (control group). The second step in the sampling design is the frame construction. A list of farmers involved in Diligent's Jatropha business was identified with field officer support. A total of 102 farmers' households (family roster: 611 people total), from two different villages in two different regions were interviewed. Additionally, the selection of respondents was done randomly with the assistance of a village chairman and a field officer.[25] In

[24] In Village I, some farmers sell Jatropha seeds to Diligent without a formal contract. The contract has been offered to most of them and Diligent treats them as outgrowers.

[25] A stratified sampling procedure cannot be used due to the lack of official population statistics for the villages (only available 2002 census). The sampling method was one of the major problems of the selection because records are not clear or properly registered. Help from the village chiefs and field officers were essential in putting together

the Village I, more than 50% of the household are involved in Jatropha business since Jatropha is grown as fencing in the village. According to Diligent records, there are 24 people in Village I under contract from 2006 (only 20 of them have been located). In Village II, Jatropha is promoted by Diligent through collaboration with the local credit cooperative (SACCO). Diligent has stipulated 200 contracts in Village II since 2007, but almost 3,000 farmers have already been contacted by the local credit cooperative and 80% of them have already attended a Diligent training course.[26] Following the criteria elaborated by Ellis and Mdoe (2003), a general picture the wealth in Tanzania village society is evaluated. The well-off are benchmarked by owning four or more hectares of land, five or more cattle, five to ten or more goats, educated to at least primary Standard VII, owning bicycles, often owning nonfarm service sector businesses, and enjoying year-round food security. According to those criteria, Figure 2 represents the radial graph of the wealth categories across the whole sample, divided by outgrowers, growers, and the control group.

Figure 2: Radial graph of the wealth categories for three groups of farmers according to Ellis and Mdoe (2003)



Source: Own calculation following Ellis and Mdoe (2003) categorization

In the areas selected for the case study, all categories of farmers live on less than one dollar a day for each person in their household, subsistence agriculture and livestock business is the major activity. More than 50% of the farmers have obtained the primary standard seventh grade

a list of farmers and their affiliation. In Diligent's database only about 30% of all farmers are currently listed. Moreover, the selection of non-contracted farmers in the villages is based on the newest population data provided by the respective village executives.

[26] The characteristics are similar among different groups. A self-selection in contracts participation is possible. Data on the socio-economic status of the study area and the availability of support services were extracted from reports, documentary materials, and from relevant institutions .

certificate in school. In the sample, 33% of outgrowers, 42% of growers, and 27% of the control group have second income sources beyond the agriculture sector given by off-farm activities. Outgrowers own an average of 2.17 hectares, 1 hectare per grower, and 1.71hectares per farmer in the control group.[27] Current measures of poverty place considerable emphasis on the ownership or access to assets (Moser, 1998). In this respect, livestock ownership is a proxy of wealth in pasture-based ethnicity groups such as Masaai. The average cattle and goat ownership is above the well-off thresholds in the selected sample based on the presented criteria. 56% of the outgrowers, 33% by the growers and 50% of the control group owns bicycles. Food security is considered by calculating the total days of shortage of food in a month and the results comply with the threshold.

3. Economic aspects of Jatropha production in outgrower scheme

3.1. Economic implications

Biodiesel generates a new demand for agricultural products and provides an opportunity for more value-addition in agricultural production (Dufey, 2006). In general, biodiesel production is economically viable through a combination of high oil prices, government tax holidays, and subsidies for a minimum purchasing price that takes into account farmers' opportunity cost of producing other cash crops. Potential value-added for farmers includes the possibility to scale-up the production, and selling or using final products (soap, lamp oil, fuel cakes for cooking, etc). The expectations about the target market for Jatropha oil vary widely in the absence of developed end-markets. Diligent has identified Jatropha oil as a potentially good diesel substitute in Tanzania. In the national market Jatropha oil is promoted as a niche product and Diligent identifies safari companies interested in using Jatropha oil as a sustainable fuel in modified car engines. There is a lack of research on whether Jatropha oil is more suitable for export to the international markets or better used domestically for rural electrification projects or for transportation (blended with diesel). For instance, most of the actors in biofuel markets in Tanzania think that Jatropha as a diesel substitute should be exported in order to gain scarce

[27] In Tanzania, the chief of the village who "owns" the land and distributes titles on behalf of the government usually determines land title ownership. Titles to use land are inherited over generations and can be sold. Usually small holder farmers cultivate their land, generating a crop surplus that can be sold on the local market. Farmers usually look for additional jobs and sell their labor in other activities, reducing working time on their own farms. This may lower the farm's yields, and hence lower income from the food surplus sold.

foreign exchange for Tanzania; whereas others believe that the Jatropha oil is better used domestically for local rural electrification projects, as an ingredient in bio-diesel blends that could be sold in the major urban centers, or for substituting fossil fuel for power generation. A second market that is being investigated is connected to the use of Jatropha seedcake for biogas production, and as charcoal or stove briquettes.[28] The lack of proper market analysis for the productive use of seedcakes is a major weakness in the development of the Jatropha innovation system. Productive use of the seedcake (which still contains about 50% of the oil) is crucial in making Jatropha biofuels profitable (Caniels and Romijn, 2009). A key issue for growth in the Jatropha production sector is the possibility of developing a sustainable business model that would allow for the social and environmental benefits of the outgrower model.

3.1.1. Estimation of Jatropha feedstock costs

Jatropha has attracted interest as a biodiesel crop and is promoted for three main reasons: first, it is a non-food crop and it has never been used extensively before. Second, it has perceived ecological advantages related to its adaptability in marginal land and its anti-erosion effects. Third, from the investor perspective, Jatropha is a newly available feedstock that is expected to have lower production costs than other energy crops such as rapeseed, soybean (Tomomatsu and Swallow, 2007), palm, or castor oils. The cost of feedstock is a decisive factor in determining the viability of biodiesel programs since it typically accounts for 65-80% of the overall biodiesel production costs (Mulugetta, 2009).[29] Therefore, it is imperative to acquire low-priced feedstock to create a positive net return for biodiesel programs, which means identifying inexpensive and reliable ways to grow the oil plants. This implies consequences on revenue for farmers.

The Diligent Jatropha biodiesel scheme has three main phases: i) Farmers recruitment; ii) Plantation stage and feedstock production; iii) Extraction stage and SVO production (including the transesterification process where SVO is transformed to biodiesel); and iv) Sale stage. In this section the analysis is limited to the second and to the third stages. Jatropha requires little

[28]Kakute, a Tanzanian NGO, conducted an experiment with a small biogas plant, which yielded mixed results because of unreliable gas pressure. There were no experiences with Jatropha as fertilizer or briquettes (Caniels and Romijin 2009). Kakute has a small Jatropha-oil lamp factory to use Jatropha oil as kerosene substitute but no market for the lamp was found. Soap is another product obtained by Jatropha oil and it shares a small niche market due to its high price.

[29]In a comparative analysis of feedstock costs among different countries, Mulugetta (2009) shows the break-even cost of palm oil (Ghana), Jatropha (Tanzania) and castor (Kenya) at a 9% discount rate, are respectively $112, $240, and $325 per ton assuming all other costs remaining constant.

management, irrigation, or fertilization (Francis et al., 2005) and after the first two years it is pest and disease resistant (Jones and Miller, 1993).[30] The establishment of a Jatropha plantation is an investment with late returns: Jatropha produces its first fruits after two rainy seasons and then the yield gradually increases until reaching the full maturity in four to five years (Kempf, 2007). Therefore, the investors must be able to afford this "waiting period. This is a crucial issue in the outgrower scheme where the delay of benefits can discourage farmers.[31] Generally, a tree can produce up to 1 Kg/tree of seeds per year in the first two years. In the third year the production is around 3 Kg/tree and from the fourth year the yield can be around 5 Kg/tree.[32] In the case study, Jatropha is grown as hedges along the perimeter of crop fields. Distances between trees in hedges is around 0,30 meter and average area of farms planted with Jatropha is 400 meters in length (perimeter of one hectare) for a rounded total of 1,250 trees per hectare and a very conservatively[33] estimated yield of 1.5 kg/tree, which equals 1,875 kg/ha of seeds when Jatropha is planted as a fence. Diligent provides outgrowers with free seeds or seedlings to plant.[34] Table 2 represents an estimation of the feedstock production costs considering costs of labor in the village and estimating the time invested in Jatropha farming in several years of production.[35] The calculation is elaborated with an estimation of the number of men working per hectare (man/ha) and salary per hectare and varies between $0.38-1.54 USD man/ha[36] according to the type of work required.

[30] This implies that it is relatively undemanding of capital inputs, and therefore suitable for cultivation by smallholders in developing countries.

[31] For an example of a solution adopted by a company, Marli investments in Zambia plans to subsidize farmers who are willing to intercrop Jatropha in more than five hectares for a year.

[32] Jatropha seed yields can vary from 0.5 tons per hectare in arid conditions to 12 tons per hectare in optimum conditions (Francis et al., 2005). With a density in intercropping of about 1,300 plants/ha (2.5m distance between the plants in a row, and 3m distance between the rows), this amounts to about 6.5 ton of Jatropha seed ha/year

[33] In the sample, yield estimation is very conservative as 1.5 kg per tree at full maturity due to the poor soil conditions and the increased tree density in the fence. The yield in rain fed conditions is around 40% lower than with irrigation. Jatropha requires a certain level of rainfall to produce a high yield (see Tomomatzu and Swallow, 2007). For example Jatropha in hedges in dry land (rain fed) in Mali has a yield from 0.8 kg to 1kg of seed per meter of live fence (Henning, 2002). Yields range from about 0.4 tons/ha in first year to 5 tons/ha after three years.

[34] Diligent usually assigns 1 kg seeds (around 1,200 seeds) to each farmer per acre (0.40 ha) in order to have 600-1,000 viable trees (assuming a loss of about 30 %).

[35] In rural areas, agricultural labor is hired seasonally and no labor is hired for Jatropha farming. The forecast considers standard cash crop data and estimation is based on interviews with field officers and management.

[36] The legal minimum wage in Tanzania for the agricultural sector is approximately US$30 per month (Labour Act, 2004). Average daily wage data for agricultural job is estimated by interviewing local government representatives.

Table 1: Projection of Total yield of Jatropha as hedges in semi arid soil (kg/ha)

	year 1	year 2	year 3	year 4	year 10
Yield (kg/ha)		250	937	1,875	1,875

Table 2: Estimation of Jatropha seeds production costs per hectare ($/ha)

	men/ha per total days of work			
Description	**year 1**	**year 2**	**year 3**	**year 4**
Land preparation ($/ha)[37]	$15.38	-	-	-
Weeding ($/ha)	$6.92	$3.46	$3.46	$3.46
Planting seeds ($/ha)	$9.23	$0.00	$0.00	$0.00
Pruning ($/ha)	-	$6.92	$6.92	$6.92
Harvesting ($/ha)	-	$9.62	$36.06	$72.12
Dry and Cleaning seeds ($/ha)	-	$0.24	$0.90	$1.80
Tot production costs ($/ha)	**$31.54**	**$20.24**	**$47.34**	**$84.30**
Tot production costs ($/kg)	-	$0.08	$0.05	$0.04

Source: Own calculation

In the projection found in Table 2, the number of working days varies proportionally to the different production stages. Since Jatropha is a perennial tree, the land preparation and planting costs occur only in the first year. Harvesting requires a large amount of man/days and it represents the higher costs in the production chain. In the second year, the harvesting cost is 48% of the total cost and in the fifth year it is 91% of total cost.[38] Jatropha harvesting process cannot be mechanized easily and, as mentioned above, economies of scale are hard to achieve. It is estimated that in a plantation the work required is 0.8 man/ha with a day salary of around $1.54/day. A discount rate of land is not considered because Jatropha is use as fence and does not involve total land utilization. In the sample, there are two harvests a year. The first stage

[37] Costs are calculated referring to the following:

		Man/day per ha	unit cost per ha
Land preparation	unit cost per ha	10	$ 1.54
Weeding	unit cost per ha	6	$ 1.15
Planting the seeds	unit cost per ha	6	$ 1.54
Pruning	unit cost per ha	6	$ 1.15
Harvesting	unit cost per kg		$ 1.15
Drying and cleaning seeds	unit cost per kg		$ 0.38

[38] In the calculation, the harvesting rate of 30 kg of dry seeds per day (4kg/hour) has been considered (Kempf, 2007); Henning (2004) gives a picking rate of only 2kg of dry seeds per hour.

production (third year in Table1) gives a maximum yield of around 937 kilograms of Jatropha seed per hectare.

In the outgrower scheme, investors bear the additional costs in seed transportation and collection (see Table 7). Diligent set up collection centers to accumulate reasonable amounts of seeds and organize transport to Arusha for processing.[39] Collection centers are strategically located in the villages[40] and provided with cash, so that farmers can be paid in advance when they deliver their bags of harvested Jatropha seeds.

3.1.2. Economic opportunities for farmers

Farmers are the key actors in Jatropha production outgrower schemes. Maximizing livelihoods, alleviating severe poverty, and gaining access to energy are usually the main reasons why farmers grow Jatropha. In the sample, 88% of respondents identify Jatropha as an extra income opportunity and 4% started to grow Jatropha only because of the incentives they received. In the rural areas identified for this research, farmers perform subsistence agriculture based on production of maize and cassava. Ugali (maize-mush) is the main staple food for the rural population and maize surplus, onions, and beans are the main cash crops for the local market in Village I. In Village II, sunflower is the most important cash crop. There are several important considerations to be made in evaluating the cost opportunity for farmers who start the Jatropha production and sign a contract with Diligent. First, areas where Jatropha is promoted are usually dry and there are not many other crops that can be grown. Maize is mainly produced for household use at subsistence level and only beans are sold on the local market. As stressed earlier, when Jatropha is planted as fence it does not compete with other cash crops. Therefore, it is not correct to consider the opportunity-cost of growing Jatropha compared to other crops because there is no competition for soil. Nevertheless, to explain the potential for farmers, one must assess the Jatropha average revenue per hectare compared to other cash crops already available in the field (Table 3). In fact, Jatropha generates higher revenue compared to sunflower

[39] To date, processing seeds into oil is conducted only in Arusha, but Diligent plans to extend it in different locations the future to lower the seeds transportation costs, which is one of the steps that is necessary to exploit Jatropha on a commercial basis.

[40] In Village I for example, Diligent has approached shop owners to require them to establish a collection point close to their shops. The shops are usually in the main market square. Shop owners are well connected to community life and they have more possibilities for advertising and/or providing information about Jatropha.

(the main cash crop in Village II) and lower revenue than beans and onions (the main cash crop in Village I).

Table 3: Average crop revenue per hectare

Commodities	Price on local market per kg	Yield per ha (kg)	Average revenue $/ha
Maize	$ 0.21	1,000	$ 209.79
Beans	$ 0.77	642	$ 493.85
Peagion pea	$ 0.38	718	$ 276.15
Cassava	$ 0.10	2165	$ 208.17
Sunflower	$ 0.38	340	$ 130.77
Jatropha[41]	**$ 0.12**	**3,750**	**$ 432.69**
Onion	$ 0.21	2,888	$ 598.11
Sweet potatoes	$ 0.08	1,900	$ 146.15

Source: Ministry of Agriculture, Food and Cooperatives and FAOSTAT

Whatever the revenue estimates, planting Jatropha for fencing rules out competition with any other cash (or food) crops. Even in terms of labor use by farmers, the competition between Jatropha and other crops is unlikely because the Jatropha harvesting season coincides with the period of time known as dry (or hunger) season that occurs from the time after planting and before harvesting maize.

In Village I, Diligent purchases seeds at $0.15/kg at the farmers' fields. In all other areas (and in Village II) the price is set at $0.12/kg at the farmers' fields. A minimum price of $0.08/kg is guaranteed to protect farmers from adverse market fluctuations.[42] Table 4 presents a projection of yearly gross income a farmers selling Jatropha to Diligent. Different scenarios are presented related to change in production yield and prices. According to the typology of the contract implemented by Diligent, the minimum price guaranteed for farmers is $0.08/kg, Diligent buys Jatropha at the farm in Village I at a price of $0.15/kg (set as maximum), and the average price is $0.12/kg.

Table 4: Projection of yearly gross income for a single farmer for selling Jatropha

Year	Yield as hedges kg/ha	Minimum price $0.08	Average price $0.12 (in Village II)	Maximum price $0.15 (in Village I)
year 3	937	$72.08	$108.12	$144.15
year 4	1,875	$144.23	$216.35	$288.46

Source: Own calculation. All prices in US$.

[41] Jatropha planted as a fence has an average yield in optimal condition of 3 kg/tree (higher than the conservative measure of 1.5 kg/tree adopted for the analysis).
[42] Jatropha seeds purchase price is identify between $0.12-1.15 US$ per kg in East Africa (Swallow, 2005).

In rural areas, the introduction of Jatropha as additional cash crop and the potential creation of a new external market may be crucial for poverty reduction, and can stimulate new investments in human capital. It can also prompt new energy supply strategies. It is then crucial to assess whether the cultivation of Jatropha can be profitable for local farmers to ensure that they are willing to keep cultivating it. The calculation of expected profits assumes that input costs (seeds) are covered by Diligent, but does not consider any additional incentives or pre-financing to farmers. Potential changes in land value are also not considered. The purchase price per kilogram of Jatropha seeds paid by Diligent to farmers plays a central role in this calculation and three scenarios are simulated (in Table 5). The effect of feedstock production costs on farmers' labor is evaluated in terms of net income per day of work. According to the data collected through farmers' interviews, the cost of labor has been calculated at around $1.54 (the average salary for a man per hectare in rural area of Tanzania) and adjustments are made using different prices for different kind of production phases.

The main assumptions of the model are:

- Costs of labor correspond to the cost of hiring workers for farming activities.
- During the Jatropha farming process, a worker cannot be hired in any other field and cannot work in his own field.
- The opportunity-cost of prolonging the cropping season to include Jatropha farming is zero for individual workers (as there is no productive alternative to harvesting Jatropha in the "dry season").

The sensitivity analysis of income per day projection (Table 5) shows three different scenarios for the price of Jatropha set by Diligent: the minimum price ($0.08/kg), the average price ($0.12/kg), and the maximum price ($0.15/kg). Risks exist for farmers entering the business. Investments in the first year in terms of labor imply a net loss of $1.19 per day per 28 working days at the discount rate of 20% calculated on the profit. Hence, the initial investment (in terms of labor) is around 28 working days per hectare at a projected total cost of labor of approximately $31 per hectare in the first year.

Table 5: Sensitivity analysis of farmers' income per day from Jatropha cultivation

	Year 1	Year 2	Year 3	Year 4
Kg per tree	-	0.20	0.75	1.50
Total production (kg/ha)	-	250	937	1,875
Total production cost ($/ha) (see Table 2)	$31.54	$20.24	$47.34	$84.30
SCENARIO 1				
Price of seed ($/kg)	$0.08	$0.08	$0.08	$0.08
Revenue from sale of seeds ($/ha)	$0.00	$19.23	$72.08	$144.23
Profit ($/ha)	$-31.54	$-1.01	$24.74	$59.93
Discount rate 20%[43]	$ -26.28	$ -0.70	$14.32	$28.90
Number of days worked (days/farmer/ha)	22.00	18.00	43.00	76.00
Income per day ($/day)	$-1.19	$-0.04	$0.33	$0.38
SCENARIO 2				
Price of seed ($/kg)	$0.12	$0.12	$0.12	$0.12
Revenue from sale of seeds ($/ha)	$0.00	$28.85	$108.12	$216.35
Profit ($/ha)	$-31.54	$8.61	$60.78	$132.05
Discount rate 20%	$-26.28	$5.98	$35.17	$63..68
Number of days worked (days/farmer/ha)	22.00	18.00	43.00	76.00
Income per day ($/day)	$-1.19	$0.33	$0.82	$0.84
SCENARIO 3				
Price of seed ($/kg)	$0.15	$0.15	$0.15	$0.15
Revenue from sale of seeds ($/ha)	$0.00	$38.46	$144.15	$288.46
Profit ($/ha)	$-31.54	$18.22	$96.81	$204.16
Discount rate 20%	$ -26.28	$12.65	$56.03	$98.46
Number of days worked (days/farmer/ha)	22.00	18.00	43.00	76.00
Income per day ($/day)	$-1.19	$0.70	$1.30	$1.30

Source: Own calculation

Capital costs (seeds) are provided by Diligent. Therefore, the first year loss should be paid upfront by the investors to enable farmers to sustain the initial expenses so they may improve their business and expand plantings. Without a loan it seems unlikely that farmers would invest in increasing Jatropha production.[44] Nevertheless, results show that the salary per working day is positive from the second year in the scenarios where Jatropha price is higher than minimum price per kilogram. If the price of Jatropha rises up to $0.15/kg growing Jatropha becomes very profitable for farmers: (almost) double the agricultural daily wage. In this perspective, growing Jatropha fencing is profitable because farmers maintain the entire salary earned from other crops

[43] The discount rate of 20% was over estimated from the Monthly Economic Review report of January 2009 from the Central Bank of Tanzania. In 2008 it was 16%.

[44] Also providing farmers with soft loans and ensuring that they get good prices for their crops is usually the main poverty reduction strategy adopted. The provision of soft loans would enable farmers to spend more time on their farms and hence increase yields. Moreover, the loans would help farmers to increase their farm sizes (Philip, 2007).

and earn an extra income from the second year of Jatropha production, with no additional work required in the traditional cropping season.

In sum, shifting land use from other cash crops, such as beans or sunflower to Jatropha, does not seem beneficial to farmers and may be hazardous to development. However, Jatropha provides a good income supplement for farmers when combined with the cultivation of other crops. Furthermore, Jatropha can grow in marginal soil where other crops will not thrive enabling farmers to obtain income from otherwise idle. Jatropha harvesting is very labor intensive and this would lead to an increase in labour demand in the community, precisely when the demand is lowest (as the Jatropha harvest season is different than traditional crops). If the market becomes competitive, an increase in returns for Jatropha production would coincide with a higher number of hired workers and a higher salary. Therefore, the production of Jatropha feedstock would also increase the land value.

3.1.3. Jatropha business competitiveness

Farmer promotion is one of the main expenses in Diligent's business plan[45] in the first years of activity. Promotion costs are calculated between 20% and 30 % of the total costs of Jatropha SVO production up to the third year.[46] The promotion costs are mostly fixed recurring expenses: they do not decrease significantly after the third year since planting, because extension services are still needed to support farmers. However, due to the expected increase in seeds production, these costs account for only 4% of total production. When Jatropha seeds are at the SVO production factory, the first step in the process is pressing seeds.[47] After pressing, the sedimentation process takes five to six days after which time it is possible to proceed with filtration where small sediments are removed from the oil.[48] Diligent produces one liter of SVO and 2.8 kg of press cake from 3.8 kg of Jatropha seeds. In the full maturity scenario (illustrated

[45]Data collected with interviews with Diligent management and compared to data on the literature on Jatropha biodiesel production, and have been adjusted to consider local labor costs and match farmers' reports. Most of the processing data were extracted from studies conducted by: Shapour et al. (2006), Shumaker et al. (2003), Von Lampe (2006), McAloon et al, (2000), and Roger (2007).

[46] Promotion costs include farmers recruiting costs, training courses lea by field officers, hiring support staff (in the case of Village II, members of the local Credit Cooperative Society are paid to liaise field officers with farmers), input provision (seeds), and the establishment of extension services (field officers give support to farmers in the first stage of plantation).

[47]Diligent has a small press worth about $5,000. With this device 400 kilograms can be pressed per day.

[48]After the oil is filtered it is ready to use in modified engines. At the moment the process is not completed with the transterification stage, which transforms oil in biodiesel that is suitable to be blended with diesel.

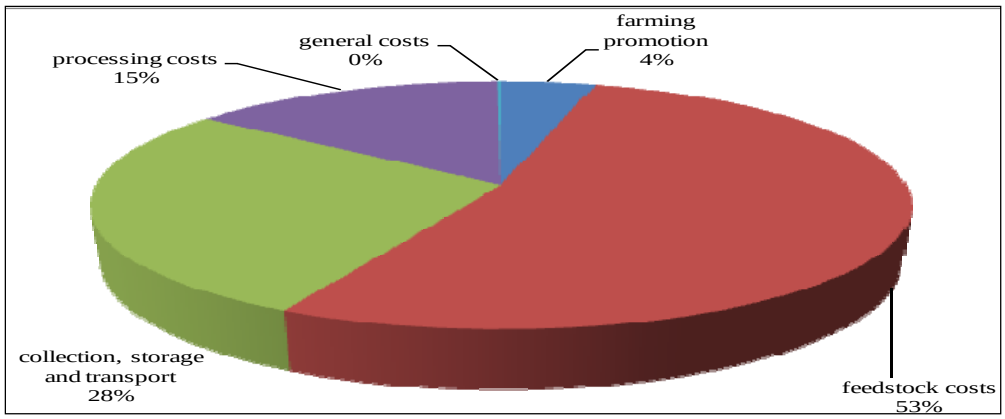
in Table 6), the final total production cost of one liter of SVO Jatropha oil will be $0.686 if the system follows the forecast.[49] Table 6 shows that Diligent can trade SVO for approximately $0.89 per liter with an estimation of 30% gross margin over the production cost. The profitability of the investments is very dependent on the production costs, but more on the end-market.

Table 6: Share of costs for SVO production in the year 10 of activity (full maturity)

	3.8 kg of Jatropha seeds	=	1 liter SVO	+	2.8 kg press cake
Farming promotion costs (contracting) ($)	0.038		0.030		0.008
Feedstock costs (purchasing seeds) ($)	0.456		0.365		0.091
Collection cost transport and storage ($)	0.220		0.190		0.030
Processing costs ($)	0.119		0.100		0.019
General costs (admin, management) ($)	0.001		0.001		
Total production costs ($)	**0.834**		**0.686**		**0.148**
Gross margin	30%		30%		30%
Sale price (without taxes) ($)	1.084		0.892		0.192

Source: Own calculation: SVO production weights for the 80% of the total cost

Figure 3: Share of costs per liter of SVO. Year 10 of activity



Source: Own calculation

Transporting the seeds and storage at the Diligent factory located in Arusha are major costs in the SVO production process. Diligent estimates that transport and storage costs account for the 28% of the total cost. Table 6 presents per unit transportation costs from Village I, which is located 62 miles from Arusha ($0.03/kg of unit cost for Jatropha seeds). Adding in the costs of handling and storage, the total cost is around $0.22 for the 3.8 kilograms of seeds that are used

[49] According to Diligent manager, oin January 2009 Jatropha oil is sold at $1.84 per liter. It is not a competitive price with average diesel price of $1.20/l in January 2009 (EWURA, 2009).

for producing a liter of SVO (Table 6). Table 7 presents four different transportation costs scenario for a liter of SVO according to distances.

Table 7: Different scenario for transportation costs (distance based)

Distances to Arusha	unit price $/kg	transport cost ($/l SVO)	total collection, storage, transport cost ($/l SVO)
local transport	0.010	0.038	0.138
under 70 miles	0.032	0.122	0.222
up to 250 miles	0.040	0.152	0.252
from Dar es Salaam (400 miles)	0.050	0.190	0.290

Source: Own calculation from personal management communications

3.2. Diesel price required to make Jatropha SVO production competitive

In 2008, Tanzania imported over 11.3 million barrels of various refined petroleum products through the port of Dar es Salaam.[50] To determine whether a Jatropha oil market is feasible, a careful comparison of the world price of diesel and the price of Jatropha oil is needed.[51] The assumption made throughout the simulations is that vehicles and machines running on pure SVO perform comparably to diesel (Rao et al., 2009)[52] and therefore diesel price in considered in the analysis. This comparison covers only i) the diesel price at the port of Dar es Salaam, and ii) Jatropha SVO production at the processing factory. Domestic retail and internal transportation costs are not included in this comparison. The landed diesel price is calculated by adding the CIF rate and the local cost payable at port authority in Dar es Salaam,[53] which is around 16-20% of the FOB price. Jatropha price is considered (as in Section 3.1.) at local production cost of $0.69 per liter. Table 8 shows that Jatropha SVO can be competitive (net of additional costs) at a diesel price of $90 per barrel.

[50] This was 5% of GDP for that year, a heavy burden on the balance of payments.
[51] The world price of Jatropha oil is not officially internationally established. GEXSI (Global exchange for social investment, http://www.gexsi.org/) estimated the price for Jatropha oil at $726/ton in June 2009.
[52] Diesel fuel has higher viscosity than SVO and the calorific value of SVO is approximately 10% lower than mineral diesel because of the presence of oxygen in their molecular structure. The cetane number of SVO is lower than mineral diesel. The optimum fuel injection pressure for Jatropha is taken as 200 bars and is the same for diesel.
[53] Landed costs include Wharfage (1.6 % of CIF), destination inspection (1.2% of FOB) SUMATRA (Surface and Maritime transport Regulatory Authority) ($0.25 per MT), TBS (0.20% of CIF), TIPER fees ($0.15 per MT), Transit loss (0.5%), and CIF Demurrage Finance Cost. Other oil taxes after landing include fuel levy, excise duty, and EWURA levy. Importers of petroleum pay 55% of the FOB price as tax.

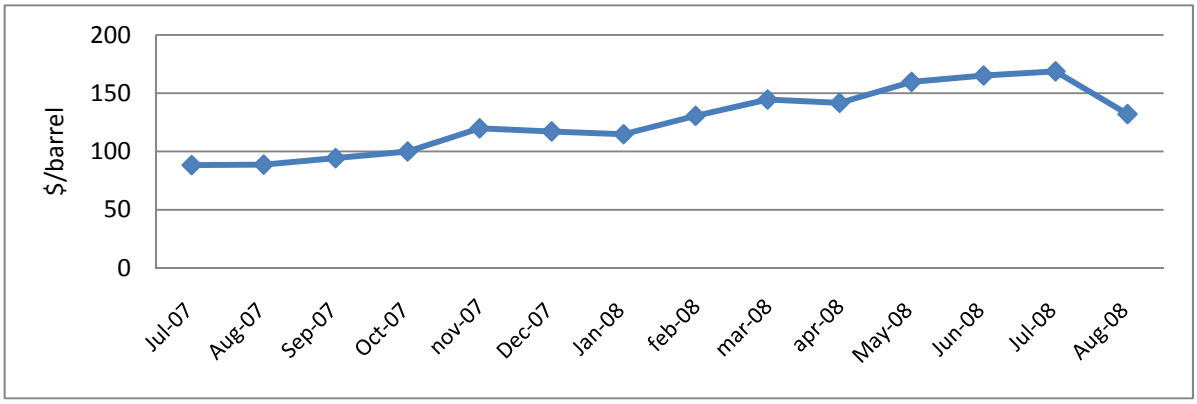
Table 8: Minimum diesel price required for competitive Jatropha SVO production

$/barrel diesel (FOB)	Diesel (Landed price) $/barrel	Diesel (Landed price) $/l	Jatropha SVO cost comparison $/l
$60.00	$72.00	$0.46	-$0.22
$70.00	$84.00	$0.53	-$0.15
$80.00	$96.00	$0.61	-$0.07
$90.00	**$109.00**	**$0.69**	**$0.00**
$100.00	$120.00	$0.76	$0.08
$110.00	$132.00	$0.84	$0.16
$120.00	$144.00	$0.91	$0.23

Source: Own calculation

Considering the world refined diesel price FOB in 2007-2008 ($80 to $120 in Figure 4) producing biodiesel from Jatropha is profitable. Given the high probability of a decrease in the Jatropha biodiesel production price and the forecasted trends in diesel prices there is a good chance that Jatropha SVO profitability will increase in the near future.[54]

Figure 4: World Market Refined Diesel FOB Prices ($/barrel)



Source: EWURA (2008)

Tanzania has a complex taxation system for petroleum products consisting of three main taxes (excise duty, road toll, and value added duty), which add about 45% to the landed price in official data (EWURA, 2008) of the total price paid by the final consumer. Oil marketing companies in Tanzania claim the retail price of diesel is 150% over the landed price. The production of biodiesel in the country would require either sustained high world oil prices or drastic reduction of feedstock costs and increased productivity of Jatropha. A reduction in Jatropha production costs is not likely in the near future, because of the adverse effects it would

[54] For example, the target landed price of Jatropha oil in Northern Europe is reported to be $0.48-0.50/l, compared to other major biodiesel sources: US$0.63 for palm oil, US$0.80 for soya oil, and US$0.94 for rapeseed oil (D1 Oils, 2007). Jatropha could be used to produce a barrel of fuel for around $43, less than $45 of sugarcane-based ethanol and $83 of corn-based ethanol (Barta, 2007).

have on farmers' livelihood. Currently a biodiesel plant does not incur any taxation during the first five years of operation due to government investment incentives. Despite this, sector-targeted government support would be crucial for attracting new investment in biodiesel production in the country. Negative environmental impacts due to the increasing use of fossil fuels and the potential poverty alleviation impacts of biodiesel production should encourage governments to introduce a "sustainability premium" to attract investments. For example, if biodiesel were exempted from VAT it would be competitive with diesel. A clear blending policy could also help develop a sustainable domestic market. Despite diffusion of tax incentives, some authors (Parry and Small, 2005; De Gorter and Just, 2010) argue that mandates to blend biofuels with gasoline might deliver better results more efficiently.[55] Recent trends in consumer behavior show that a sustainable biodiesel production, which take development and poverty reduction issues into account can increase consumers' willingness to pay a higher price for a sustainably produced good. The growth of a formal Jatropha sector would also contribute to energy security in Tanzania and result in spillovers to the industrial sector. The promise of providing a reliable source of bioenergy for the whole country could, if correctly weighted with policy, provide a strong argument in favor of Jatropha promotion in Tanzania. Creating a demand for biodiesel could potentially reduce fuel prices in general and reduces oil imports in Tanzania.

Moreover, the social benefits created by involving farmers in the production chain as outgrower, as well as the accumulation of emission credits, should be evaluated as positive externalities even if they are difficult to be monetized. Nonetheless, greenhouse gas emissions, carbon stocks, and air quality externalities are already measurable by well-defined indicators. They can be monetized on the basis of their impacts on health, global warming, and soil and water quality. Some externalities still need good indicators to be measured: land use change, health, soil quality, water quality, and biodiversity. Externalities as well as the respect of working conditions and property rights, and the increase in local wellbeing can only be evaluated through qualitative indicator (Brose and Castiaux, 2009). While it is difficult to economically assess these externalities, a deeper assessment of the implications of the outgrower scheme for the livelihoods of farmers would be important to understand its sustainable development potential. In Section 4, the paper attempts to shed some light on these implications.

[55] Both by reducing gasoline consumption (implicit tax on gasoline) and by saving tax costs (reduce deadweight costs in labor market).

4. Socio-economic drivers of sustainable biofuel production

4.1. Indicators and approaches

Several research and international organizations argue that sustainable development is a complex dynamic interaction between environmental science and economic, social, and development studies (Kasemir et al. 2003).[56] Therefore more than 500 projects have been devoted to designing comprehensive quantitative indicators set for sustainable development (Parris and Kates, 2003; Lewandowski et al., 2006) and there is a very weak consensus on sustainability criteria. Referring to bioenergy, measurable indicators have been agreed on to assess its environmental sustainability, such as energy balance and greenhouse gas balance, but most of the social and economic criteria are still only locally applicable and are difficult to quantify and measure. Identification of those criteria is crucial to operationalize sustainability assessments of bioenergy systems, identify good practices, and remain responsive to the values expressed by stakeholders at the local level (Buchholz et al., 2009). In particular, this paper considers the social benefits for farmers in terms of perceived access to services to measure wellbeing[57]. In recent years, there has been an increase in economic research on "subjective wellbeing approaches" to sustainability also connected to the "individual capabilities approach"[58] developed by Amartya Sen (1997). Subjective wellbeing is generally identified with life satisfaction and happiness evaluation (Inglehart, 2008; Layard, 2005; Frey and Stutzer, 2002). The study of happiness or subjective wellbeing is part of a more general move that challenges the economic assumptions of neoclassical microeconomic theory. People have different preferences for material and non-material goods and a welfare evaluation that focuses purely on income can miss key elements for a correct assessment. The economics of happiness does not purport to replace income-based measures of welfare but instead complements them with broader measures

[56] Since the Rio conference (1992), the tripartite description (social, economic, and environmental) has been the basis for the generally accepted definitions of sustainable development (OECD, 2001).

[57] The social dimension is often included in a broader definition of human development (Harris et al., 2001) which is referred to as the ability of human beings to satisfy their essential needs: to achieve a reasonable level of comfort, to live lives of meaning and interest, and to share opportunities for health and education.

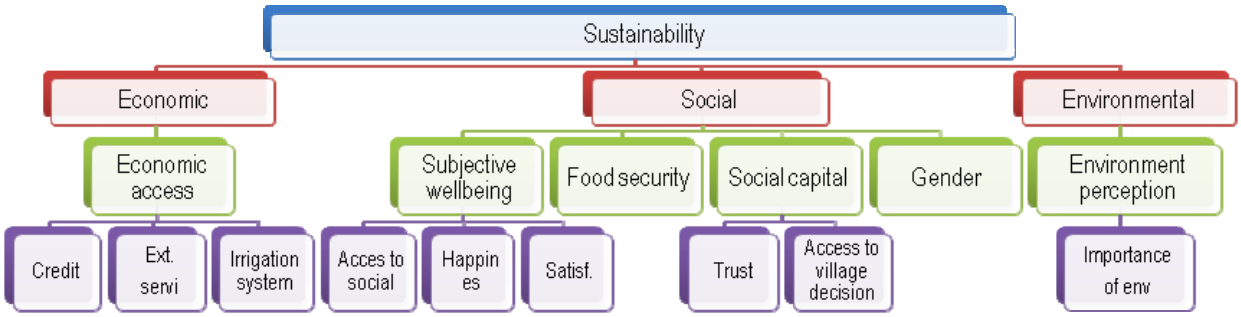
[58] Sen's approach affirms that policies should not (only) focus on collective outcomes such as the distribution of income, but rather on building individual capabilities, and ensuring that people have the freedom to convert economic wealth into outcomes they desire. Capabilities are combinations of functionings that an individual can achieve. Functionings denote the various things a person may value doing or being—varying from elementary functionings like nourishment and shelter to complex ones such as self-esteem and participation (Sen, 1999).

of wellbeing (Graham, 2008).[59] Subjective wellbeing is indexed and enters directly into the quantification of policies for sustainable development. The contribution of this research is in the introduction of subjective indicators in the construction of a more general indicator for sustainable development. In this view, this paper presents a first attempt to merge the growing literature on happiness and subjective wellbeing to the operational needs of a rigorous assessment of social and economic policies.

4.2. Socio-economic sustainability framework

The detailed analysis of the direct and indirect material benefit for farmers in the Jatropha business presented in section 3 has to be combined with a more comprehensive socio-economic approach. Here, a set of indicators has been designed and to make the analysis more tractable, 16 indicators have been grouped into 11 sub-themes and six main themes, which are divided between the three aspects of sustainable development found in Figure 5. The indicators have been grouped into six main themes through different methodologies as presented below.

Figure 5: Sustainability tree - hierarchical framework integration



In order to obtain valuable information about the potential consequences of Jatropha production, the research shows simple non-parametric, mean-difference tests[60] related to the indexes created. The tool is then applied to evaluate:

i) Farmers in Jatropha business (outgrowers and growers) and farmers not involved in Jatropha business (traditional farmers);

[59] Richard Easterlin was the first modern economist to revisit the concept of happiness, beginning in the early 1970s. Several more studies followed in the late 1990s (see, among others, Easterlin, 1974; 2003; Blanchflower and Oswald, 2004; Clark and Oswald, 1994; Frey and Stutzer, 2002; Graham and Pettinato, 2002; Layard, 2005).
[60] The statistical t-test assesses whether the means of two groups are *statistically* different from each other. Differences between scores of the two groups are represented by the difference between their means relative to the spread or variability of their scores.

ii) Farmers under contract (outgrowers) and all other farmers; and

iii) Farmers in the Jatropha business (outgrowers and growers) and farmers not involved in the Jatropha business (traditional farmers), by comparing the two areas.[61]

This evaluation will indicate whether a major difference between Jatropha growers and others derives from Jatropha production, or if there is a significant "perceived" effect (namely on trust and confidence) from being part of a contract scheme, such as the one designed by Diligent. Both the small sample size and the early production stage in both areas do not allow for more rigorous impact evaluation analysis tools.[62] At this stage of the Jatropha production process, only a pre-social assessment evaluated with subjective perceptions is feasible. Notwithstanding, comparing the same indexes between the two villages at a different production stage can provide a general idea of the characteristics before and after the beginning of the production stage.

The economic access perception index describes perception of access to economic services such as credit, irrigation, and extension services (training and skill acquisition). Lack of access to financial services, credit constraints, and lack of access to technologies and water are the biggest barriers to wellbeing in many developing countries (FAO, 2009). This index is constructed with the arithmetic mean of the answers to the following questions (1 is low, 7 is high):

- “How do you qualify your access to credit?”
- “How do you qualify your access to extension services?”
- “How do you qualify your access to irrigation systems?”

Analysis: The economic access index is not perceived very differently between the farmers in the Jatropha business and traditional farmers. There is a significantly higher perception in the mean difference from outgrowers compared to other farmers, in particular regarding access to credit and extension services. One of the possible explanations could be the presence of a field

[61] In the first area (Village I) the production has already started and the first harvesting season is already completed, so some outcome is observable. The second area (Village II) is at the beginning stage of contracting and planting seeds so t it can be considered as the “baseline” of the analysis.

[62] Several problems arise in the analysis. First, the selection bias of the farmers involved in the project must be considered. Nevertheless, equal opportunity for participation in the outgrower scheme has been given to all farmers. Endogeneity is a concrete risk in this sample selection and for this reason the analysis is only descriptive. According to the limitation of this analysis, further improvement in the research methodology should be applied. A statistically significant farmers sample or a randomized sample should be selected, therefore, the tool should be applied before the company starts to contact farmers and then monitoring should be continued.

officer employed by Diligent who provides support to farmers and helps to create a higher perception of extension services overall (addressed to outgrowers in particular). Moreover, the perception of better access to credit for outgrowers can be connected to their hope in Diligent's ability to provide credit facilities that will enlarge the production in the future. More than 80% of farmers report that they have high expectations that Diligent will provide easier access to credit for outgrowers in the future. By investigating the situation in the two geographical areas, it is possible to presuppose a situation before starting the production (Village II) and after (Village I), in order to predict the possible impact. The overall perceived economic access is significantly consistent among the outgrower farmers in the case of Village II where Diligent works with a local credit union to recruit outgrowers. Therefore the credit facilities in Village II highly influences outgrowers' perception.

The Subjective Wellbeing Index (SWB) is generally identified with life satisfaction and happiness evaluation (Inglehart, 2008; Diener and Suh, 1999; Layard, 2005; and Frey and Stutzer, 2002). Quality of life evaluation or subjective wellbeing (Lawton, 1997; Dijkers, 1999) explains how people feel about their lives. Data on subjective wellbeing have been introduced into economics as an empirical approximation to a notion of utility (Kahneman et al. 1997). The questions pertaining to subjective wellbeing may refer to "happiness" or to "life satisfaction".[63] Cummins (2000) has elaborated the Personal Wellbeing Index (PWI) which considers how satisfied people are within seven life domains.[64] Inglehart et al. (2008) argue that a subjective wellbeing index that combines both life satisfaction and happiness is a broader and more reliable indicator of subjective wellbeing than either component by itself. The index considers the weighted mean of the scores – ranging from 1 (low) to 7 (high) – attributed to the following questions:

- Happiness: "Generally speaking, do you consider yourself happy?"

[63] The General Social Surveys presents the question: "Taken all together, how would you say things are these days — would you say that you are very happy, pretty happy, or not too happy?" The Eurobarometer Surveys use a four-point verbal life satisfaction scale, employing the question: "On the whole, are you very satisfied, fairly satisfied, not very satisfied, or not at all satisfied with the life you lead?" In the World Values Surveys, people are offered a scale from 1 (dissatisfied) to 10 (satisfied) to respond to the question: "All things considered, how satisfied are you with your life as a whole these days?"(Welsch, 2009).

[64] In the PWI all domains are simply summed to produce a mean satisfaction value, which represents people's subjective wellbeing. These include standard of living, personal health, achievement in life, personal relationships, personal safety, community-connectedness, and future security.

- Satisfaction: "Overall, how much are you satisfied with your household's living conditions?"
- Access to water: "How would you qualify your access to drinkable water?"
- Access to education: "How would you qualify your access to education?"
- Access to health services: "How would you qualify your access to health services?"
- Access to jobs: "How would you qualify your access to employment opportunities?"
- Access to transportation: "How would you qualify your access to transportation?"

Weights are assigned to each component of the SWI, following the assumption that happiness and life satisfaction are comprehensive indicators. Therefore, they are given a combined weight of 50% (25% each) in the index construction, and the other domains are each given a weight of 10% in the index.[65]

Analysis: The Subjective Wellbeing Index (SWI) perception is significant for farmers who decided to grow Jatropha and among outgrowers in particular. In Village I, perceived wellbeing is higher among outgrowers compared to the same index in Village II, where Jatropha production will mature in two years. Therefore, it is possible to expect an increase in the mean difference between outgrowers and other farmers in Village II once that the production stage is reached and outgrowers will be repaid for the investments and will perceive longer term stability in supplying seeds to Diligent. In particular, the highest indicator among all aggregated indicators is happiness. A self-evaluation of happiness[66] as a whole (not necessarily connected to Jatropha business) is a good proxy for both the individual's personality and reaction to life events (Stevenson, 2008). In the case study, satisfaction evaluation is more connected to overall household living conditions and is slightly higher among outgrowers in Village I than in Village II, where there is not yet material impact from Jatropha production. Possibly an analysis on the satisfaction level in Village II when the production stage is achieved will give a further dimension of the significance and validity of the indicators.

Social capital is measured in various ways and has often been found to have a strong impact on subjective wellbeing (Diener and Suh, 1999; Helliwell, 2003; Helliwell and Putnam, 2004; Kroll,

[65] WELLBEING = (happy*w_1)+(satisf*w_1)+(access_school*w_2)+(access_health* w_2)+ +(access_job* w_2) + (access_water* w_2)+(access_transport* w_2)/($\sum_{i=1}^{n} wi$) w_1=0.25 and w_2=0.1

[66] Although the validity of these measures remains a somewhat open question, a variety of evidence points to a robust correlation between answers to subjective wellbeing questions and more objective measures of personal wellbeing (Stevenson 2008; Easterlin, 2003)

2008; Tov and Diener, 2008). Ostrom (1999) argues that individuals are able to make credible commitments when they learn to trust each other. Hence investments made in one time period can produce higher levels of return in the future even though the individuals creating trust and reciprocity are not fully conscious of the social capital the are constructing (Ostrom, 2000). Social capital index is considered using two different social capital definitions. The first is connected to the social capital dimension, which concerns the notion of generalized trust (Knack, 2003; Knack and Keefer, 1997).[67] The second dimension of social capital is the notion of participation in local decision making processes (Dekker and Uslaner, 2001) and is connected to the sense of civicness as argued by Putnam. In the social capital index, both trust dimensions have been included based on the following questions:

- Generally do you feel like you can trust members of your community? (dummy 0-1)
- Do you feel that you can trust people from outside your community? (dummy 0-1)
- How do you qualify your access to village decision-making? (1 is low, 7 is high)

The index is computed as the arithmetic mean of the three social capital questions and the third question is standardized between 0 and 1.

Analysis: Among the other social indexes, social capital is perceived as higher among outgrowers because of a difference in mean regarding the perception of access to decision making. Observation regarding level of trust can be endogenous. Outgrowers declared higher levels of trust in people outside the community, but inversely causality may occur. This result may show that being involved in a contract could be particularly effective in increasing farmers' trust towards others as a result of building commercial and fiduciary relationships with people from outside the village.

Food security is a key issue in the bioenergy debate as 44% of the Tanzanian rural population is undernourished (FAO, 2008a). Biofuel production can have a direct effect on food production and land use through a reduction in cultivated crops and land availability and a negative impact on agricultural system diversity. In outgrower systems, biofuel feedstock production can increase cropping diversity to some extent, as well as providing reliable cash cropping, but attention

[67] It may be interpreted as a general predisposition toward people you do not know (Uslaner, 2002) and may be defined as "a trust that goes beyond the boundaries of kinship and friendship and even beyond the boundaries of acquaintance" (Stolle and Rochon, 1998, p. 48).

should be given to measuring crop and dietary diversity as an overall indicator of food security (Ruel, 2002). In the presented case study, Jatropha does not cause crop substitution. Food insecurity is measured by the number of days in a month with food shortage. It is not directly dependent on biofuel production, but it can be connected to the opportunity to ensure food security even before harvesting main crops. This index is a dummy that represents the perception of having enough food in the last 12 months (value equal to1, 0 otherwise).

- Did you feel like you were running out of food in the last 12 months?

Analysis: Food security index is perceived higher only by outgrowers, and in the case of Jatropha growers in Village I where they have reached production stage. A possible explanation is connected to the feeling of stability of additional yearly income provided by the contract in the mid-run (at least ten years). Furthermore, the Jatropha harvesting period is on average long (from January to May) compared to other cash crops. Hence farmers can receive cash immediately when they sell Jatropha at a collection center for a longer period of time in the year, and in particular before they start harvesting other cash crops. Contract seems to give farmers a higher perception of food security and outgrowers report lower food shortages in the last year.

Gender: In rural areas of Tanzania, women make up 86% of the agriculture labor force and contribute to 60% of food production (ADB, 2005). Men and women have different roles and responsibilities within rural economies, as well as pre-existing socio-economic inequalities (Rossi et al., 2008). Most of these disparities have implications for the country's growth potential and in agriculture in particular, which is likely to remain below its productivity frontier because of women's unequal access to land and other resources (IFC, 2007). Women farmers in rural areas hold the less fertile, marginal land and they undertake the most time consuming activities, such as fetching water or collecting firewood.[68] Furthermore, if land traditionally used by women switches to energy crop plantations, the role men and women play in decision-making concerning household agricultural activities may be altered. In particular, women's ability to participate in land-use decision-making may be reduced as the amount of land they control will

[68] The majority of rural women travel an average of three hours walking distance per day for collecting firewood. In the study area, 100% of women gather fuel wood and water for the household. Seebens (2006) argues if the ten hours a week spent on wood and water collection were reduced by one hour, the probability of women engaging in off-farm business would increase by seven percent. Therefore, investments in timesaving infrastructure such as piped water and modern or more accessible household energy have the potential to increase women's capacity to participate in off-farm income-generating activities.

decline (FAO, 2004; FAO, 2004b; Wooten, 2003). Gender aspects in the agriculture related decision-making process is critical to selling the crops and to use of income derived from the sales, typically because women manage household food security. Evidence shows that in the majority of the cases, men decide the type, price, and quantities of crops to sell, while only 25% of households use a joint (male and female) decision making structure (ADB, 2005). Unilateral decisions could be driven by personal needs and not necessarily driven by the welfare of the family ADB (2005). This index is a dummy that represents a decision taken together (husband and wife) in the household about agriculture production (value equal to 1, 0 otherwise). The answer has been given by the husband, but confirmed by the wife. The original question is:

- Who in the household decides which crops to grow?

Analysis: The index does not show any significance in the mean difference between groups. The empirical result of the sample is higher than the Tanzanian national average, which indicates that women are involved in farming decisions in only 25% of households (ADB, 2005)

Environment is connected to biofuels through direct and indirect land use impacts, carbon stock decreases, water depletion and pollution, biodiversity loss, and air quality degradation (Menichetti and Otto, 2009). Jatropha is perceived by farmers as a possible solution to avoid soil erosion and to protect crops from wind and animals. Moreover, the training course on Jatropha is focused on the need to protect soil. This awareness can generate a positive approach to the overall environmental conservation, establishing a virtuous cycle in environment protection.[69] This index refers to a general question on the importance of environmental preservation. How important is to preserve the environment? (1 is low, 7 is high)

Analysis: The importance of environment preservation is particularly perceived among outgrowers and those who attended Diligent information courses. Environmental index mean difference is significant in Village I where the Jatropha production cycle is already complete. Higher environmental perception given by the Diligent information campaign could explain this

[69] Rangel (2003) found a positive relationship between economic security and concern for preserving environmental quality for future generations. Welsch (2002) measures self-reported wellbeing to examine the trade-off between prosperity and environmental quality. Ferrer-i-Carbonell and Gowdy (2007) use micro-level data and find robust correlations between individuals' subjective wellbeing and environmental awareness and attitude.

result and is probably the best explanation concerning the result experienced in growing Jatropha in very arid soil.

Table 9: Indexes results from the non parametric test

	Farmers in Jatropha business		Farmers not in Jatropha business			
	Mean	St.Dev	Mean	St.Dev	Min	max
Economic	2.39	1.14	2.07	.76	1	7
Subjective wellbeing	4.48***	.59	3.81***	.95	1	7
Social capital	.70	.16	.68	.18	0	1
Food security	.69	.46	.60	.49	0	1
Gender	.71	.45	.66	.47	0	1
Environment	6.07	1.22	5.72	1.15	1	7

	Outgrowers (with contract)		Farmers without contract			
	Mean	St.Dev	Mean	St.Dev	Min	max
Economic	2.78***	1.05	1.85***	.82	1	7
Subjective wellbeing	4.45**	.66	4.10**	.86	1	7
Social capital	.74**	.15	.65**	.17	0	1
Food security	.77**	.42	.57**	.49	0	1
Gender	.70	.45	.68	.46	0	1
Environment	6.20**	1.25	5.74**	1.13	1	7

	Village I				Village II			
	Farmers in Jatropha business		**Farmers not in Jatropha business**		**Farmers in Jatropha business**		**Farmers not in Jatropha**	
	Mean	St.Dev	Mean	St.Dev	Mean	St.Dev	Mean	St.Dev
Economic	2.14	1.19	1.83	.78	2.68*	1.02	2.20*	.74
Subjective wellbeing	4.50***	.72	3.03***	1.08	4.45	.41	4.25	.49
Social capital	.65	.15	.66	.09	.76	.16	.78	.21
Food security	.48**	.50	.08**	.28	.93	.24	.90	.30
Gender	.64	.48	.41	.51	.78	.42	.80	.40
Environment	5.94**	1.05	5.08**	.99	6.21	.24	6.09	.23

4.2.1. Analysis of the model

Subjective wellbeing index is one of the most interesting result of the analysis and it confirms how further analysis can show potential increase in individual wellbeing at an advanced level of Jatropha production over time. Individual answer to the aggregated index are analyzed according to the following model as a linear function of independent variables

$$SWB = \beta_0 + \beta_0 x_1 + \beta_2 x_{2+\cdots+} \beta_k x_k + \varepsilon \qquad (1)$$

Function (1) is estimated by means of an ordered logit regression.[70] Each of the regression coefficients describes the size of the contribution of a variable for individual wellbeing.[71] Second, it is assumed that the answer to the subjective wellbeing question provides an ordinal (and not cardinal) ranking. Third, ordinal interpersonal comparability is assumed.[72]

Table 10: Subjective wellbeing index. OLOGIT regressions

	Eq 1	Eq 2	Eq 3	Eq 4	Eq 5	Eq 6	Eq 7	Eq 8	Eq 9
treatment	1.250***	1.328***	1.213***	1.237***	1.217***	1.191***	1.275***	1.291***	1.232***
	(0.40)	(0.40)	(0.40)	(0.40)	(0.40)	(0.40)	(0.40)	(0.40)	(0.40)
tot_livestock	0.008	0.008	0.008	0.008	0.012	0.012	0.012	0.013	0.017*
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
hhnum	0.196***	0.240***	0.248***	0.232***	0.201***	0.226***	0.238***	0.248***	0.256***
	(0.07)	(0.07)	(0.07)	(0.07)	(0.07)	(0.07)	(0.07)	(0.07)	(0.07)
gender	0.766	1.253	0.877	0.684	1.433	0.371	0.519	0.169	0.478
	(1.06)	(1.03)	(1.01)	(1.03)	(1.01)	(1.07)	(1.10)	(1.12)	(1.12)
age	0.009	0.008	0.004	0.009	0.011	0.004	0.005	0.008	0.008
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
mstatus	0.265	0.431	0.234	0.171	0.840*	0.152	0.279	0.176	0.583
	(0.39)	(0.39)	(0.38)	(0.38)	(0.43)	(0.39)	(0.41)	(0.41)	(0.47)
edu	0.386*	0.422**	0.433**	0.454**	0.506***	0.351*	0.321	0.336*	0.397*
	(0.20)	(0.20)	(0.19)	(0.19)	(0.19)	(0.20)	(0.21)	(0.20)	(0.21)
ENVIRONMENT2	0.299*					0.308*	0.300*	0.268*	0.173
	(0.16)					(0.16)	(0.16)	(0.16)	(0.16)
FOODSECURITY		1.158***					1.025**	1.196***	1.019**
		(0.43)					(0.44)	(0.44)	(0.45)
economicaccess			0.368**			0.388**	0.313	0.170	0.261
			(0.19)			(0.19)	(0.19)	(0.20)	(0.21)
SOCIALCAPITAL2				2.256**				2.287**	2.028*
				(1.04)				(1.13)	(1.14)
decision_both					1.319**				1.018*
					(0.54)				(0.59)

[70] Micro-econometric happiness equations have the standard form: $W_{it} = \alpha + \beta x_{it} + \varepsilon_{it}$ where W is the reported wellbeing of individual i at time t, and X is a vector of known variables including socio-demographic and socioeconomic characteristics. Unobserved characteristics and measurement errors are captured in the error term. Because the answers to happiness surveys are ordinal rather than cardinal, they are best analyzed via ordered logit or probit equations. These regressions typically yield lower R-squares than economists are used to, reflecting the extent to which emotions and other components of true wellbeing are driving the results, as opposed to the variables that we are able to measure, such as income, education, and marital and employment status (Graham, 2008).

[71] A positive regression coefficient means that that an explanatory variable increases the probability of the outcome, while a negative regression coefficient means that a variable decreases the probability of that outcome. A large regression coefficient means that the risk factor strongly influences the probability of that outcome. This implies that SWB is a categorical variable and thus we can observe the range in which it lies, but not an exact level.

[72] This means, for example, that an individuals' mean SWB index is "6" and the individual is better ranked than one answering "3", but not necessarily twice as better (Ferrer-i-Carbonell and Frijters, 2004).

Obs	101	101	101	101	101	101	101	101	101
Degrees of freedom	8	8	8	8	8	9	10	11	12
R-squared	0.0467	0.0521	0.0472	0.0484	0.0500	0.0525	0.0604	0.0661	0.0704

Note: OLOGIT = ordered logit regression; Robust standard errors are in parentheses. All estimates include the following control variables: farmers involved in Jatropha business (treatment), livestock owned (tot_livestock), household dimension (hhnumber) age, sex (gender), marital status (mstatus), education (edu). * p<0.10, ** p<0.05, *** p<0.01

The results presented in Table 10 indicate the relationship between general socio-economic characteristics, subjective indices, and measures of subjective wellbeing. In particular, the fact of being involved in the Jatropha business either as grower or outgrower has been evaluated as an independent variable[73] (treatment) in the regression. For each subject who enters the Jatropha business (treatment), his ordered log-odds of being in a higher reported subjective wellbeing (SWB) level would increase by 1.19 to 1.32 (Table 10: Eq 1 to 10) when the other variables in the model are held constant. The variable "treatment" is significant at 1%. One unit increase in household members' number (hhnum) would result in a 0.19 to 0.25 unit increase in the ordered log-odds of being in a higher SWB category when the other variables in the model are held constant. Education results are also significant in most of the equations (Eq 1 to 9). In particular, reaching one grade higher in the education scale would result in a 0.32 to 0.45 unit increase in the ordered log-odds of being in a higher SWB category when the other variables in the model are held constant. In Eq 1 to 5, each index is individually entered in the regression. In Eq. 1, a unit increase in the environmental perception would result in a 0.29 unit increase in the ordered log-odds of being in a higher SWB category when the other variables in the model are held constant. The environmental index is significant also when economic access, food security, and social capital are considered. In Eq. 2, individuals whom perception in food security is positive (equal to 1) have a 1.15 ordered log-odds more than others of being in a higher SWB score when the other variables in the model are held constant. Food security is also significative with the introduction of all other variables (Eq. 9). In Eq. 3, a unit increase in the economic access self reporting consideration would result in a 0.36 unit increase in the ordered log-odds of being in a higher SWB category when the other variables in the model are held constant, significant at 5%. The economic index is also significant when the environmental index is introduced. Eq. 4 shows that the ordered log-odds for who have a positive (equal to 1) social

[73] Some farmers grow Jatropha and sell Jatropha seeds to Diligent without a formal contract. For the purpose of this research I consider these farmers as "outgrowers" and include them in my "treatment group" made of people who work with Diligent using the outgrower scheme.

capital value of being in a higher SWB category is 2.25 higher than individuals who have a negative (equal to 0) social capital value. Social capital index is still significant at 5% when variables as environment, food security, and economic access are considered. It is significant at 10% level even when all indexes are introduced. Households where decisions are made by both husbands and wives have 1.31 ordered log-odds of being in a higher SWB score (Eq. 5). Sharing decisions in the household is still significant when all variables are considered (Eq. 9).

4.3. Potential social benefit: outgrower scheme evaluation

In countries where small-scale agriculture continues to be widespread, an outgrower approach appears to have considerable potential since many small-scale farmers cannot compete without access to the services provided by contract farming companies. Well-managed contract farming is an effective way to coordinate and promote agricultural production and marketing and is common practice in agribusiness.[74] Shortages of reliable and cost-efficient input such as extension advice, mechanization services, seeds, fertilizers, and credit – as well as guaranteed and profitable markets – characterize rural farming activities. Well-organized contract farming can enable smaller producers to improve their farming knowledge. Similarly, it also provides investors with the opportunity to guarantee a reliable source of supply (FAO, 2001). Outgrower schemes can potentially make business profitable for both the investors and the farmers who otherwise would not have access to a market for their crops. To be successful it requires a long-term commitment from both parties and the ability to manage inequalities. In fact, technological and market risk distribution and exploitation by management are frequent problems. For farmers in rural areas considering a contract, benefits are only in the long run and honoring contractual arrangements is likely to be to their long-term benefit. The prime advantage of a contractual agreement for farmers is that Diligent will normally commit to purchasing all products. Farmers can potentially use the contract agreement as collateral to arrange credit with a commercial bank to fund inputs. The main potential advantages for farmers are: Provision of inputs and production services; access to credit; introduction of appropriate technology; skill transfer; guaranteed fixed pricing structures; and access to reliable markets.

[74] Critics of contract farming tend to emphasize the inequality of the relationship and the stronger position of investors with respect to that of growers. Outgrower schemes are viewed as essentially benefiting investors by enabling them to obtain cheap labor and to transfer risks to growers. However, evidence indicates that it represents a way of reducing uncertainty for both parties. Furthermore, it will inevitably prove difficult to maintain a relationship where benefits are unfairly distributed among investors and growers.

From the empirical analysis of the case study appears that farmers with a contract have received free seeds and training to grow Jatropha. Only 10% of farmers report that substantial land preparing assistance has been provided. A fixed price guarantee has been introduced to all contracts, but only 20% of the farmers know about it and only 5% know the amount of it. Communication should be more clear and transparent in order to inform farmers about the benefits of the contract and to enforce the contract itself. The major problem faced by investors is related to their ability to obtain the expected quality and volume of crops. Appropriate codes of conduct and law enforcement for both companies and farmers can also mitigate the frequency of contracted farmers selling to opportunistic competitors on the side. Building strong relationships based on trust networks and a participatory approach results in lower transaction costs for the company. Small credit facilities established for farmers can also be profitable. Furthermore, it can help enable the trust network with farmers and provide them with an adequate supply of quality products while introducing appropriate agricultural technology. Diligent does not use credit support facilities for farmers but it should be a best practice to implement as indicated by 60% of grower farmers. Among farmers with a contract with Diligent the satisfaction related to the assistance in growing Jatropha is high-very high (5 to 7 on a 1 to 7 grade scale) in 61% of the cases. Before contracting farmers, Diligent organizes Jatropha training courses for all who want to attend. Courses provide information about the market and explain the potential benefits of Jatropha business and the positive impact on soil erosion.[75]

5. Conclusion

Rural farmers in developing countries do not only benefit from the direct production of feedstock for biofuel in terms of increase in income, but also stand to benefit from the introduction of a reliable market for Jatropha in their area. The analysis presented in this research considers material returns for farmers and the investing company as well as non-material goods such as relationships, wellbeing, and farmers' perceptions. The production of biodiesel can have direct and indirect benefits for farmers. Some of the benefits can be seen as generalized for each cash crop in an outgrower scheme, but this paper shows the value that Jatropha SVO can potentially add compared to other crops because Jatropha is a cash crop that can grow in arid

[75] 93% of farmers who decided to become outgrowers, 28% of farmers who are growing Jatropha independently but mostly sell seeds to Diligent, and 45% of farmers (from the sample) who are not growing Jatropha, but they may be interested in knowing about it have attended the training course organized by Diligent.

areas not suitable for other crops and therefore can attract investment in those areas. Moreover, Jatropha does not need intensive care, does not compete with labor for food crops, and provides extra income at the time when cash crops are not generating revenues.[76] Additionally Jatropha has multiple uses and market potential both at the local and/or export level and, more importantly in developing countries, it does not require monoculture or land substitution because it is planted as a fence and it can provide an alternative source of energy even at the local level.

The paper presented three questions:

1. Is it profitable for farmers and companies to produce Jatropha straight vegetable oil (SVO) by implementing an outgrower scheme in Tanzania?
2. How can Jatropha SVO production be considered socio-economically sustainable for farmers?
3. Are there best practices and structures that can be implemented by biofuel investors in order to ensure that rural farmers benefit from Jatropha production?

To answer the first question, the paper evaluated the economic feasibility for the company and for the single farmer. Results show the potential direct material benefits for farmers – especially in areas where the soil fertility is very low and agriculture is challenging. However, it is worth mentioning that farmers can potentially receive additional revenue of approximately $1.24 per day from growing Jatropha, lifting the farmer up from absolute poverty ($1 per day). The opportunity to increase the per capita income of local farmers can happen without affecting other activities. The production price of Jatropha oil is compared with landed diesel price in order to determine the competitiveness and potential market of Jatropha SVO. At this stage of production there is a concrete option that profitability will increase in the near future, given the high chance of a decrease in Jatropha biodiesel price and the forecast trends in diesel prices.[77] A local energy market for biofuels should be developed to provide a clean and renewable energy source to potentially reduce oil dependency in Tanzania. Moreover, the development of an alternative use for Jatropha – the creation of Jatropha-fueled electrification programs, for example – would help mitigate both market risk and technology risk. At present, if oil prices

[76] Allowing for consumption smoothing and an increase in input investment for staple crops at the household level.
[77] Final SVO sold at local level is potentially competitive with diesel at the pumps due to high diesel taxes and transportation costs in Tanzania. SVO can be used in rural communities to supply energy and electricity. Identification and creation of a viable national and international market are among the main drivers of sustainability.

drop or the technology is overtaken by an alternative biofuel feedstock or process, Diligent takes the financial hit and cannot fulfill its contract with growers.

To answer the second question about maximizing social benefits for farmers at the local level, the paper outlines a new approach to sustainability by considering the subjective evaluation of farmers' conditions and comparing groups involved and not involved in Jatropha production. Subjective wellbeing indicators are not yet included in the sustainable development indicators literature, but they are extremely important when the multidimensional impact of biofuel cropping on rural communities is considered. The paper presents a toolkit for investigating farmers' perceptions. Results of non-parametric tests show how involvement in Jatropha activities can impact farmers' wellbeing reports and therefore their livelihood. Order logit regressions provide further evidence for the direct connection between involvement in Jatropha business and subjective wellbeing. In particular, a positive relationship to subjective wellbeing is found with social capital measurement, perceptions about environment preservation, and food security perception. Further research, including randomized experiments and monitoring are needed to evaluate projects at their different stages by using the indexes presented in the paper.

Potential best practices for sustainable development are highlighted to answer the third question for outgrower schemes. Results from descriptive analysis show the potential effectiveness of the company in creating added value in the community through the improvement of individual skills, services, local credit, and infrastructure. The analysis identifies recommendations in terms of how Jatropha could contribute to rural livelihood improvement[78] so it is important to consider that the outgrower scheme assigns both the market and technology risks to Diligent. In view of potential replication of the scheme, it would be important to include a more extensive assessment of these risks, as other profit-oriented operators might plan to share them with local producers. Knowledge sharing and skills transfer should be supported, especially in analyzing other opportunities for improving the cost effectiveness of Jatropha production – the

[78] This research shows that some targets set by Diligent were not met. It is not very easy for Diligent to have a capillary and transparent mechanism that allows trust to be built with farmers and secure seeds provision by pulling down the costs. Diligent is in the initial project phase and it has a substantial number of outgrowers contracted, but it is very costly to manage relationships. In fact, due to the high numbers of involved farmers and the comparably low number of extension officers, it may be sensible to slow down the up-scaling and rather focus on stabilizing the achievements made so far.

use of the seedcake in biogas production and as fertilizer, for example. The untapped potential of substituting Jatropha products for lamp oil, soap, diesel for generators, and fertilizer could be advantageous for local livelihood, but is not prioritized in the Diligent project. Farmers are only involved in the first part of the value chain, preventing many of the possible benefits of Jatropha to be available to rural communities, but mostly putting farmers at risk of being abandoned by Diligent if market conditions change. For this reason, the value chain should be placed locally in order to secure synergies and self-sustainability within the farmers' community. Therefore, farmers' participation should be enhanced and farmers should be motivated to self organize and find a common strategy and voice for collaboration and lobbying that will increase their empowerment. Finally, financial possibilities should be analyzed and involve suitable local partners to provide financial access to Jatropha projects, focusing on benefitting small-scale farmers.

The government can play a vital role in securing beneficial conditions for Jatropha production by implementing effective policies, and regulatory and legal frameworks with standards for a sustainable biofuels production and use. The government's position can have a crucial impact on access to finance. Accurate knowledge on Jatropha production, different practices, and the derived impacts on livelihood are essential in order to create suitable policy frameworks.

To better enhance further development of the market, a few adjustments and further lines of investigation are indicated below:

a) *Adjustment of expectations*: The farmers' investments and costs (land, labour, capital) in establishing and maintaining Jatropha is high for the first planting seasons. Jatropha becomes profitable after the second season under good environmental conditions and with good management. Therefore, farmers should be informed during the training course about all the risks of Jatropha cultivation, particularly the loss that will occur at the beginning of the investment. Risks include difficult estimation of realistic seed yields and the lack of knowledge of good agricultural practices. The potential of the Jatropha crop should not be overestimated.

b) *Improvement of transparency and involvement of farmers*: There is a need to create a more transparent relationship with farmers by giving them a tool to interpret and understand price variations. Hence, cooperation among representatives of Jatropha farmers groups should be more frequent, and the communication could be improved as farmers showed interest in

exchanging ideas and experiences with the company. Producing a farm record book where agronomic data (e.g. origin of seeds, planted trees per acre, yield in the different seasons, etc.) and observations of different events (e.g. pest occurrences, treatment effects, growth, etc.) may improve monitoring and evaluation. Additionally, the data can contribute to the improvement of Jatropha yields through research and development.

c) *Continued efforts in monitoring and evaluation and research and development*: Disseminating information on good techniques is essential. Basic technological knowledge exists in Tanzania due to widespread use of vegetable oil presses for crops such as sunflower and castor; however there is no advanced knowledge about efficient high-capacity presses for Jatropha in the country (Caniëls and Romijn, 2009). Further analysis on the elaborated sustainability framework is needed to investigate the socio-economic aspects. In particular, it would be very important to set a baseline of the analysis and combine it with constant monitoring over time. With an elaborate dataset of information, monitoring and evaluation are likely to improve. Information on costs and socio-economic aspects should be shared with government agencies, local stakeholders, and between groups in order to improve knowledge and increase efficiency in all aspects of production. Experience in agronomical issues related to Jatropha (yield, pests, etc.) should be developed and shared among farmers and stakeholders.

Considering the results, it can indeed be expected that biofuel promotion will increase the value added in the agricultural sector, thereby contributing to rural employment and development. Producing biofuels or biofuel feedstock will enable rural farmers and processing firms to access – at least indirectly – regional or even international markets (Peters et al., 2008). Nonetheless, research efforts must be intensified in order to reduce uncertainties about cost projection and market opportunities especially regarding the potential export market. The success of Jatropha development critically depends on whether production costs can be sufficiently reduced for biofuel to be viable in Tanzania and other developing countries.

Annex I: Sample descriptive statistics

Distribution of sample population by villages

Villages	Outgrowers	Growers	Control group	Total hh	% on Total Household
Village I	19	26	4	49	8%
Village II	30	2	21	53	2%
Total	**49**	**28**	**25**	**102**	

Note: % on total household is calculated on the basis of report from chief of the village about total number of households.

	Outgrower		Grower		Control Group	
	Number	percentage	number	percentage	number	percentage
A. AGE DISTRIBUTION						
Under 30	2	4%	2	10%	2	6%
30-40	10	21%	5	24%	10	30%
40-50	15	31%	5	24%	8	24%
50-60	12	25%	3	14%	5	15%
60-70	5	10%	5	24%	4	12%
Over 70	4	8%	1	5%	4	12%
	48	100%	21	100%	33	100%
B. LEVEL OF EDUCATION						
Never attended school	11	23%	7	33%	10	30%
Primary school (1-4)	3	6%	0	0%	1	3%
Primary school (5-7)	29	60%	13	62%	18	55%
O-level sec. school	5	10%	1	5%	3	9%
Diploma	0	0%	0	0%	1	3%
	48	100%	21	100%	33	100%
C. GENDER						
Male	46	96%	17	81%	28	85%
Female	2	4%	4	19%	5	15%
	48	100%	21	100%	33	100%
D. HOUSEHOLD SIZE (number of people present in the household)						
(average)	6,25		7,04		5,75	
E. FARM SIZE (acres)						
0-2.5	17	35%	10	48%	12	36%
2.6-5	15	31%	10	48%	12	36%
5.1-7.5	4	8%	1	5%	3	9%
7.6-10	5	10%	0	0%	5	15%
10.1-15	3	6%	0	0%	1	3%
15.1-20	2	4%	0	0%	0	0%
over 20	2	4%	0	0%	0	0%
	48	100%	21	100%	33	1
F. MONTHLY INCOME						
average monthly income (TZS)	65104.17		64523.81		43696.97	

Source: Own calculation

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Belfer Center for Science and International Affairs
Harvard Kennedy School
79 JFK Street
Cambridge, MA 02138
Fax: (617) 495-8963
Email: belfer_center@harvard.edu
Website: http://belfercenter.org

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